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Harmonic analysis of satellite sensed temperatures along latitudes of both hemispheres for the period 15 May to 28 July 1966

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HARMONIC ANALYSIS OF SATELLITE SENSED TEMPERATURES ALONG LATITUDES OF BOTH HEMISPHERES FOR THE PERIOD: 15 MAY TO 28 JULY, 1966

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THESIS

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by

John James Krall

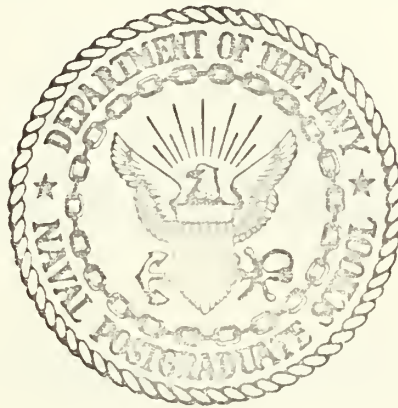Thesis Advisor: F. L. Martin

September 1971

Harmonic Analysis of Satellite Sensed Temperatures
Along Latitudes of Both Hemispheres for the
Period 15 May to 28 July 1966

by

John James Krall
Lieutenant Commander, United States Navy
B.A., University of Minnesota, 1962

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN METEOROLOGY

from the

NAVAL POSTGRADUATE SCHOOL
September 1971

ABSTRACT

The object of the study is to examine the climatology of NIMBUS II satellite-sensed window-channel equivalent blackbody temperatures for the period 15 May 1966 to 28 July 1966. Fourier analysis was applied to these temperatures at selected latitudes in the Northern and Southern Hemispheres.

The total variance, as well as the percentage contribution to variance by individual waves 1 through 8, along the selected latitudes is examined. In addition correlation coefficients between adjacent key latitudes are computed and interpreted.

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TABLE OF SYMBOLS AND ABBREVIATIONS

A_n Fourier coefficient

ANV   Additional normalized variance

B_n Fourier coefficients

C_n Fourier amplitude coefficient

F_n Statistic for significance

k Time

r_{12} Correlation coefficient

SD   Standard deviation

T_{bb} Equivalent blackbody temperature

$T(\lambda)$ Radiometeric temperature at a latitude and time

T_o Mean temperature for a latitude

ϕ Latitude

λ Longitude

σ^2 Variance

ψ_n Fourier phase angle

TABLE OF SYMBOLS AND ABBREVIATIONS

A_n	Fourier coefficient
ANV	Additional centralized variance
B_n	Fourier coefficient
C_n	Fourier amplitude coefficient
F_n	Statistic for significance
k	Time
r_{12}	Correlation coefficient
SD	Standard deviation
bb	Duplicated harmonic generation
$T(\gamma)$	Radiance in temperature at k level and mean time
T_0	Mean temperature at k level
Φ	Latitude
λ	Longitude
Q^2	Variance
ψ_n	Fourier phase angle

ACKNOWLEDGEMENTS

I. INTRODUCTION

Globally-averaged NIMBUS II window-channel radiances for a seventy-five day period are examined from the results of their Fourier analyses along selected latitudes. The NIMBUS II medium resolution infrared scanning radiometer carried a window channel (channel 2), with half-power response in the 10-11 micron range. This channel is calibrated to sense equivalent blackbody temperatures (T_{bb}) representative of the surface in clear sky areas and cloud tops in thick overcast areas. Thus, anomalously warm temperatures usually represent surface temperatures in clear areas while anomalously cold temperatures represent temperatures of the top of heavily clouded areas, except in ice-covered areas. Areas of scattered-to-broken cloud coverage and of mixed cloud types do not have these extremes of equivalent T_{bb} values, instead the values of equivalent blackbody temperatures do not differ significantly from those expected for climatological cloud top level temperatures appropriate to the particular geographic locality and season.

Fifteen successive global maps of five-day mean equivalent blackbody temperatures during 15 May 1966 to 28 July 1966 serve as the basis of the examined data. Figure 1 depicts the mean temperature field for the entire 75 day period. Figures 2 through 6 represent five consecutive fifteen-day mean maps for the period 15 May through 28 July 1966.
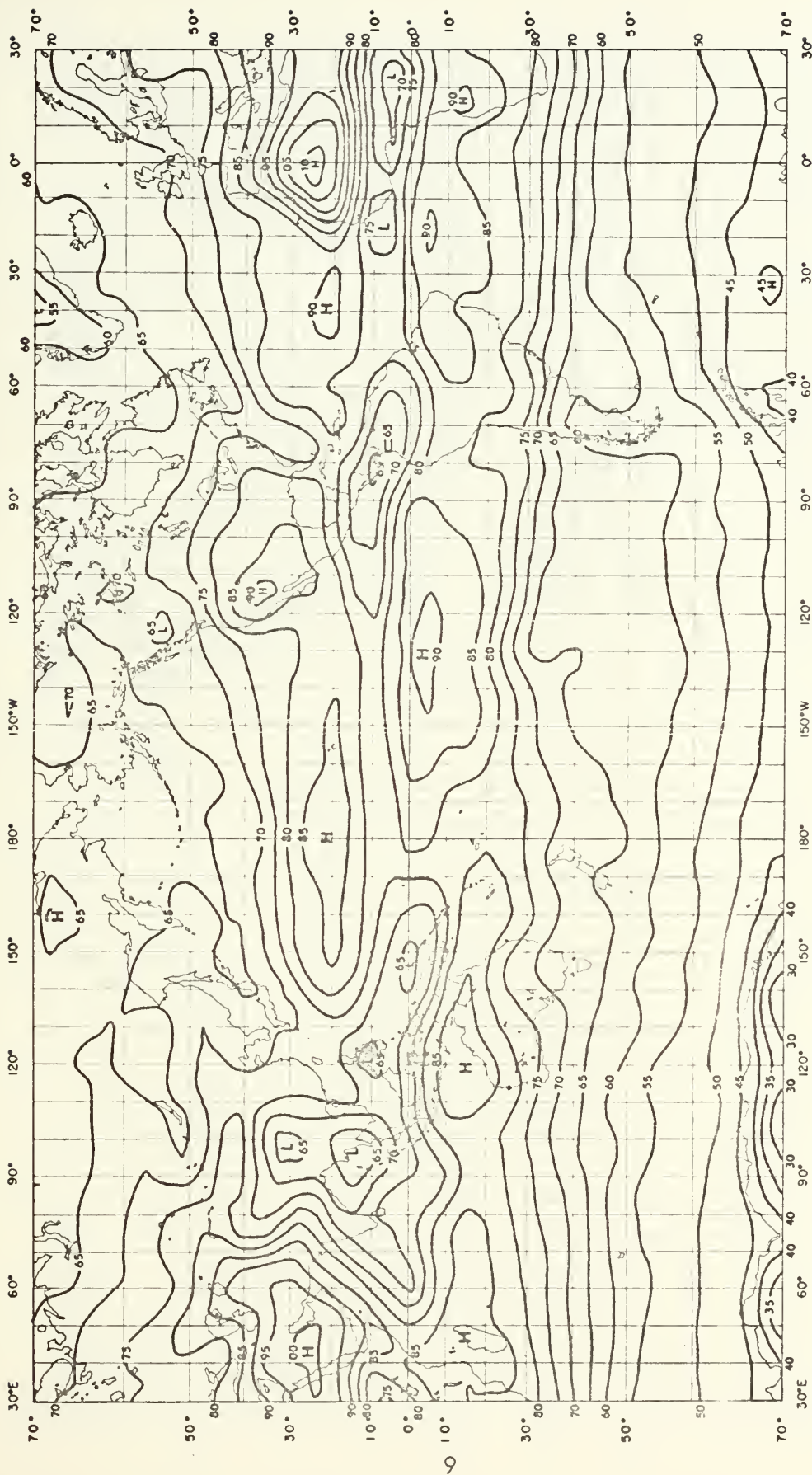
Figure 1. Mean temperature field for the 75 day period 15 May to 28 July 1966 as sensed by NIMBUS II. The temperature isolines are labeled with the last two digits of a Kelvin temperature, example: 70 = 270 degrees Kelvin.

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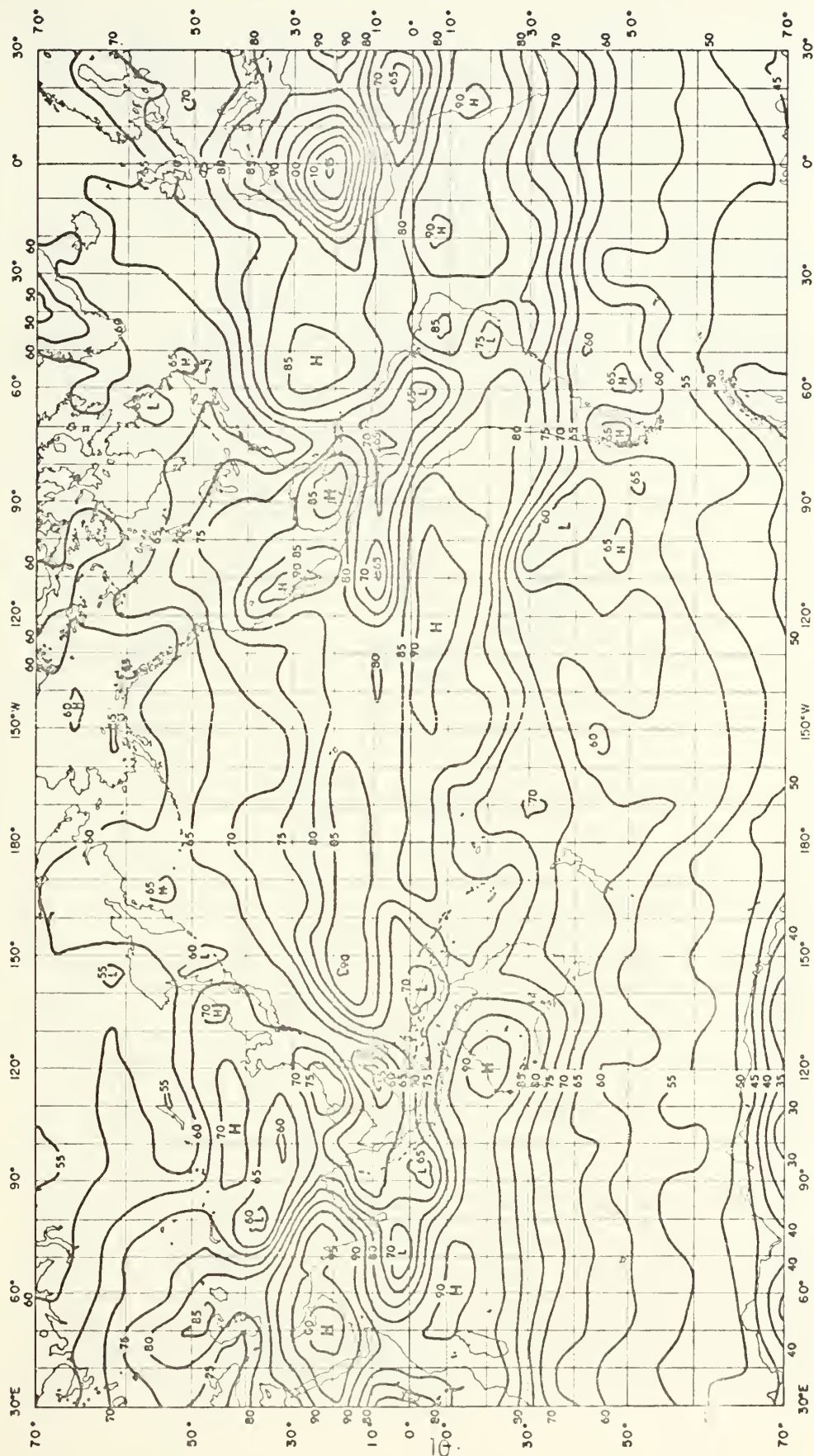
Figure 2. Mean temperature field for periods 1-3, 15 May to 29 May 1966 as sensed by NIMBUS II. The temperature isolines are labeled with the last two digits of a Kelvin temperature, 70 = 270 degrees Kelvin.

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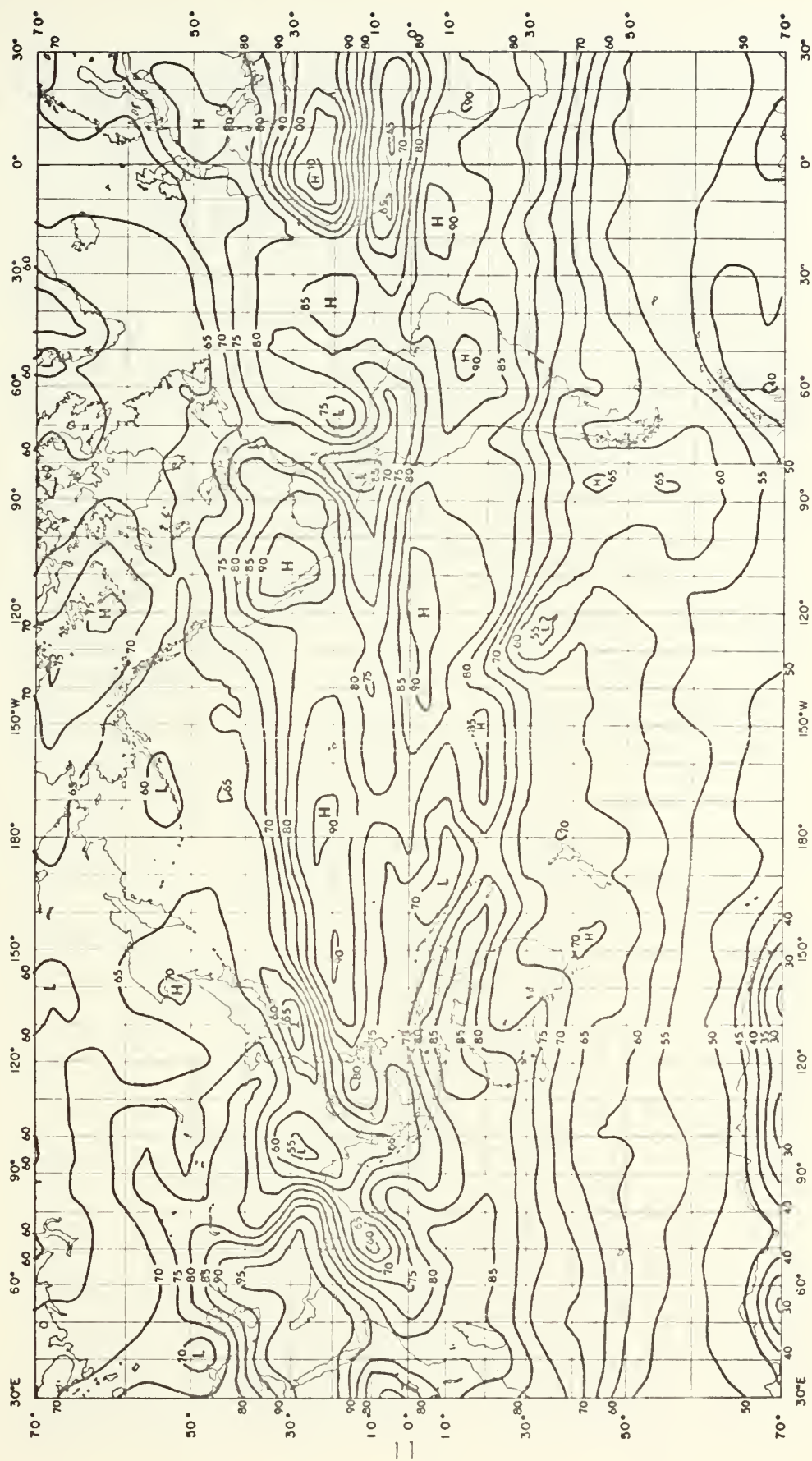
Figure 3. Mean temperature field for periods 1-6, 30 May to 13 June 1966 as sensed by NIMBUS II. The temperature isolines are labeled with the last two digits of a Kelvin temperature, 70 = 270 degrees Kelvin.

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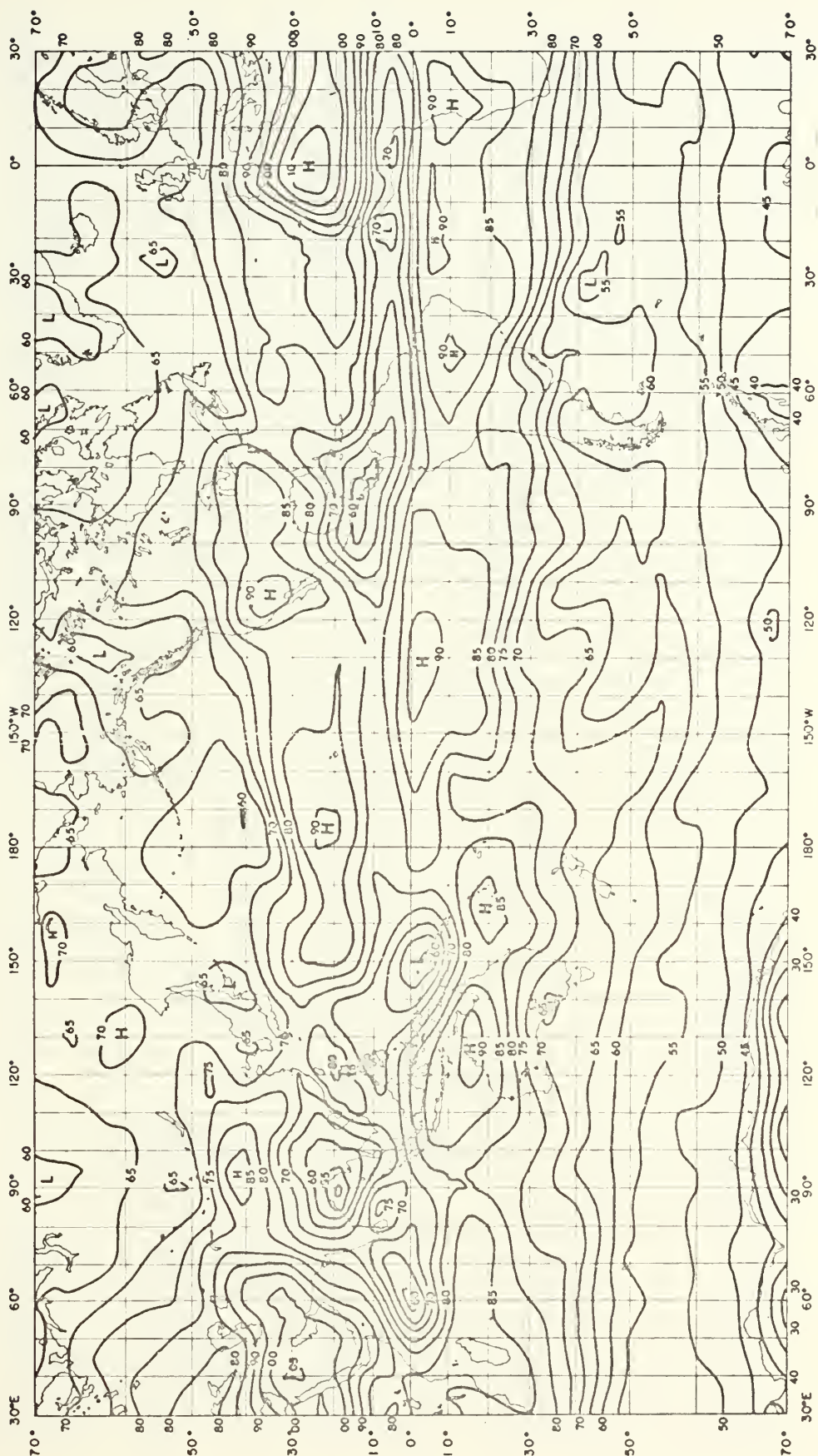
Figure 4. Mean temperature field for periods 7-9, 14 June to 28 June 1966 as sensed by NIMBUS II. The temperature isolines are labeled with the last two digits of a Kelvin temperature, 70 = 270 degrees Kelvin.

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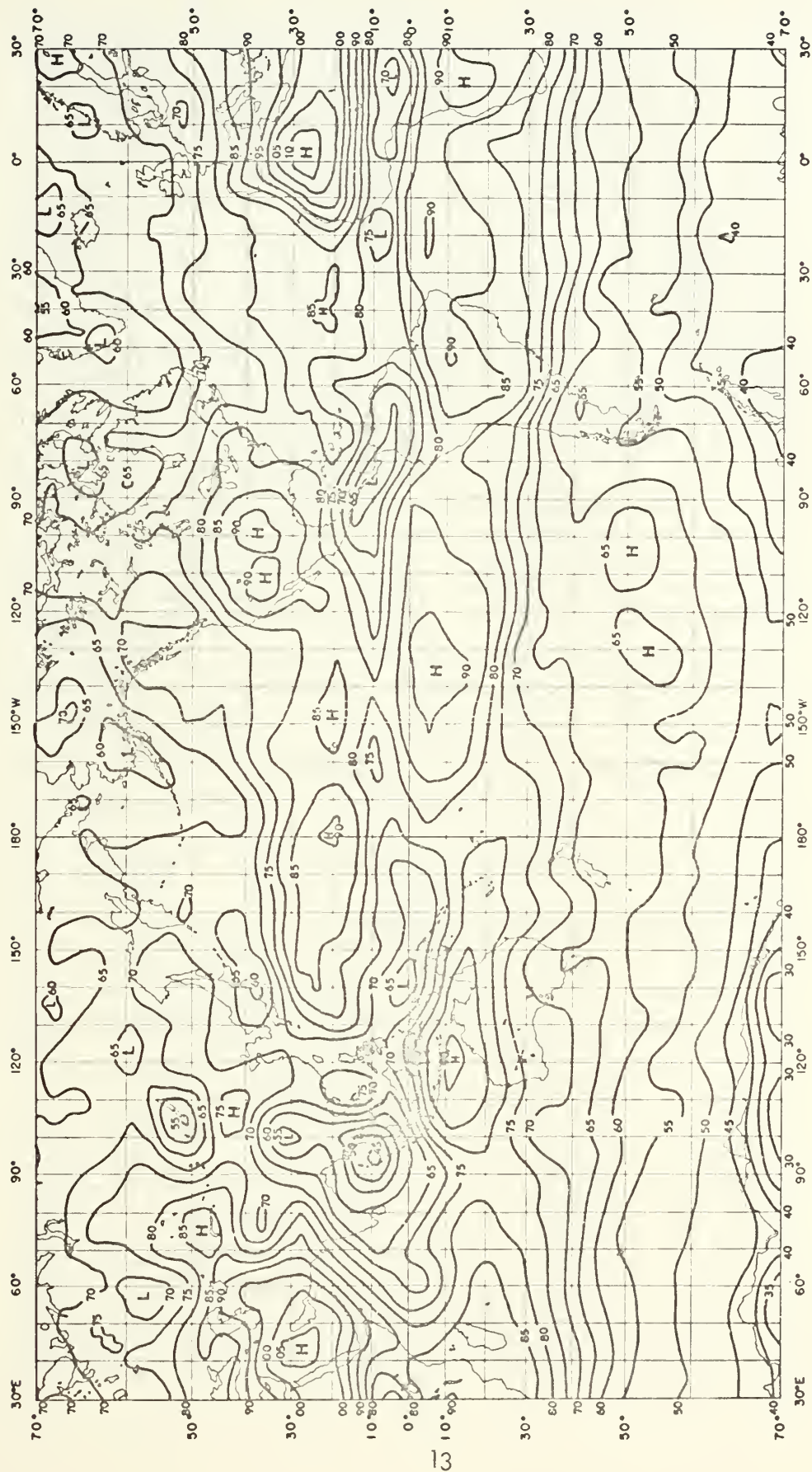
Figure 5. Mean temperature field for periods 10-12, 29 June to 13 July 1966 as sensed by NIMBUS II. The temperature isolines are labeled with the last two digits of a Kelvin temperature, example: 70 = 270 degrees Kelvin.

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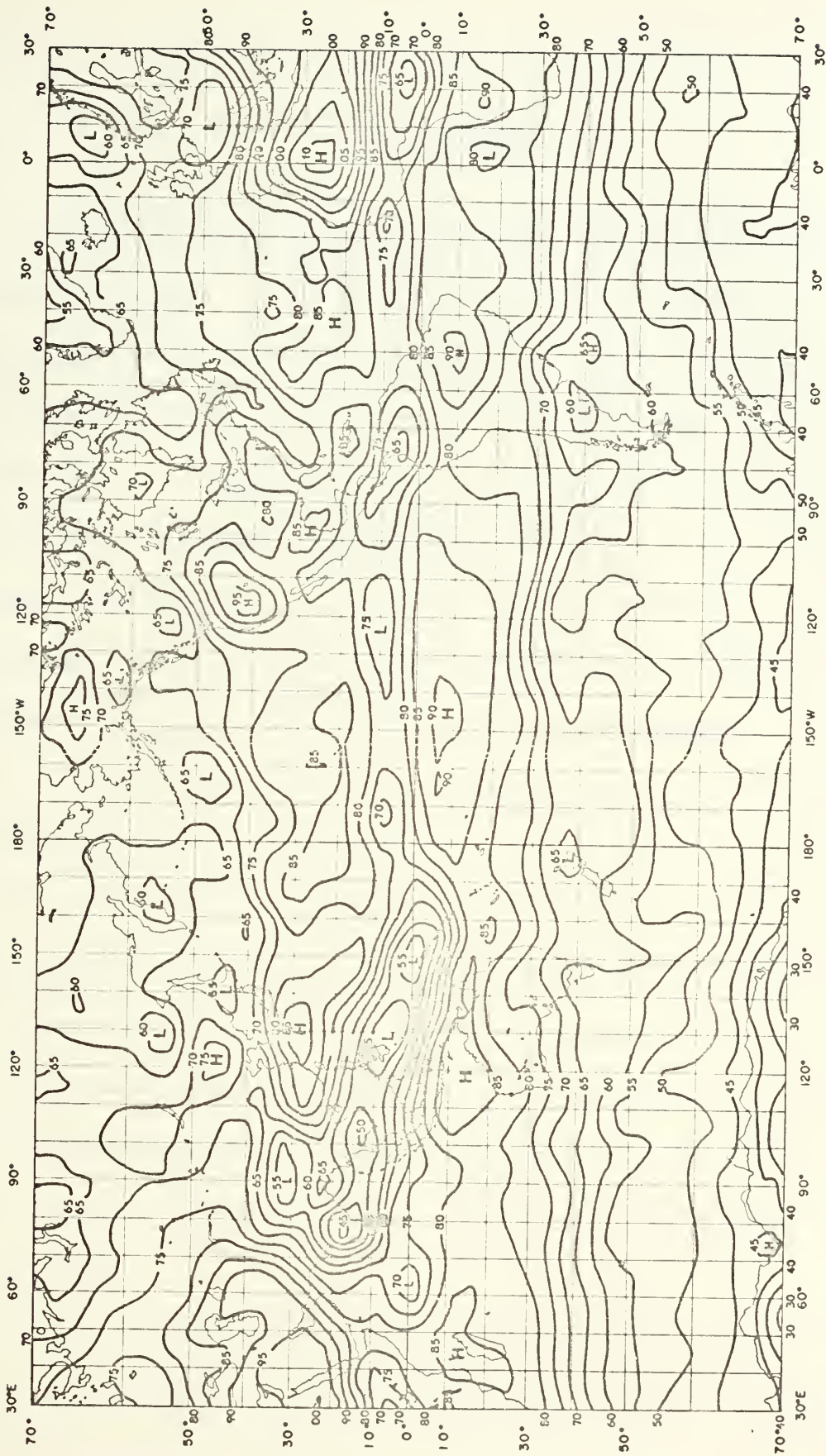
Figure 6. Mean temperature field for periods 13-15, 14 July to 28 July 1966 as sensed by NIMBUS II. The temperature isolines are labeled with the last two digits of a Kelvin temperature, example: 70 = 270 degrees Kelvin.

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II. THE DATA

The NIMBUS II satellite data of the window channel was interpreted for the effective temperature sensed, and is displayed for purposes of this study on a Mercator projection. The data was resolved at five degrees of longitude, true at the equator on a scale of 1:40M. Along each latitude, seventy-three NIMBUS II temperatures, to the nearest whole degree, were encoded in a serial manner, west to east, at five degree longitude grid point intervals. The maps utilized 40 north-south grid-mesh intervals to cover the latitude range 70S to 70N. From this array of 41 latitudes, eight key latitudes were chosen for representation of the harmonic analyses. The key latitudes selected were approximately 50N, 30N, 15N, 5N, 5S, 15S, 30S, 50S, which correspond respectively to the following latitudes resulting from superimposing the grid array on the Mercator projection, 51.0N, 28.2N, 14.3N, 4.4N, 5.6S, 15.4S, 29.2S, and 48.5S. Because latitudes of gridded data differ only slightly from key latitudes, the two sets will be considered coincident. This latitude selection was designed to determine mean amplitude and phase-relationships between (1) the mid-latitudes and the subtropics and (2) the subtropics and the tropics of each hemisphere, as well as (3) the inter-hemispheric events occurring between 5N to 5S, and the even larger region of 15N to 15S.

Since no other temperatures are to be used in this study, mean window-channel temperatures (T_{bb}) will hence forth be denoted in the functional form $T(\phi, \lambda, k)$, where ϕ = latitude, λ = longitude at five degree increments around the globe,

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and k is the time index, $k = 1, \ldots, 15$. For each five-day mean map, Fourier analyses was applied along the eight key latitudes (ϕ).

Comparision of the successive five-day mean maps shows significant spatial and temporal variability in the temperature fields. Individual weather troughs and ridges, and/or lows and highs in T_{bb}, on a five-day mean chart are easily recognized but these systems seem to oscillating about their mean positions rather than exhibiting any systematic motions. This difficulty in tracking individual features led to the selection of the Fourier analysis method to describe the climatology of the large-scale monsoonal character of the period. The results were examined and found to be characteristic of large areas in both hemispheres.

III. THE FOURIER ANALYSIS

Consider the arbitrary meterological parameter $T(\phi, \lambda, k)$ and assume that at latitude ϕ, and time k, the radiometric temperature $T(\lambda)$, may be represented around a latitude ϕ by a Fourier expansion in wave number space, such as:

$$T(\lambda) = T_o + \sum_{n=7}^{18} A_n \cos n\lambda + B_n \sin n\lambda) \tag{1}$$

Here the parameters T_o, A_n and B_n are defined as:

$$T_o = \frac{1}{2\pi_o} \int_o^{2\pi} T(\lambda) \, d\lambda \tag{2A}$$

$$A_n = \frac{1}{2\pi} \int_o^{2\pi} T(\lambda) \cos n\lambda \, d\lambda \tag{2B}$$

$$B_n = \frac{1}{2\pi} \int_o^{2\pi} T(\lambda) \sin n\lambda \, d\lambda \tag{2C}$$

The series in equation (1) could be defined for 35 harmonics because the data sample included 73 data points, but it was found that those waves above 18 represented essentially noise, not for example, real synoptic patterns of lows and highs. Hence the maximum wave number n considered in equation (1) was 18. Equation (2A) is the zonally-averaged window-channel temperature around latitude ϕ at map-time k. Also, A_n and B_n of equations (2B,2C) are obtained by integration of the function $T(\lambda)$ weighted multiplicatively by $\cos n\lambda$ or $\sin n\lambda$ respectively over each of the 72 $\Delta\lambda$ intervals for each latitude. The computer program developed also lists the percentage of the variance

$$\sigma^2(\phi, k) = \frac{1}{72} \sum_{\lambda=1}^{72} (T(\lambda) - T_o)^2 \quad (3)$$

around the latitude circle explained by the inclusion of each wave $n = 1, \ldots, 18$.

An expression equivalent to equation (1) is:

$$T(\lambda) = T_o + \sum_{n=1}^{18} C_n \cos(n\lambda - \psi_n) \quad (4)$$

where ψ_n is the primary phase angle. Comparison of equations (1) and (4) leads to results:

$$A_n = C_n \cos \psi_n$$

$$B_n = C_n \sin \psi_n \quad (5)$$

and further to:

$$C_n = (A_n^2 + B_n^2)^{\frac{1}{2}} \quad (6)$$

$$\psi_n = \arctan(B_n / A_n)$$

The phase angle ψ_n can also be viewed as the direction angle in polar coordinates of the complex number $A_n + iB_n$. Percentage contributions to the total variance by each harmonic $n = 1, \ldots, 18$, are defined as:

$$\% \text{ Explained Variance} = C_n^2 / 2 \quad (7)$$

Here σ^2 is the variance statistic for each latitude ϕ and time k identified by equation (3) and $C_n^2 / 2$ is the contribution to the total variance by the Fourier wave number n.

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In summary several useful statistics can be obtained from map-by-map decomposition of the longitudinal arrays of satellite sensed temperatures. The major statistics obtained at key latitudes and for each time period were:

(1) The mean temperature T_o

(2) The total variance σ^2

(3) The Fourier wave amplitudes C_n for $n = 1, \ldots, 18$.

(4) The percent contribution to the total variance by each wave number n.

(5) The primary phase angle ψ_n, $0 \leq \psi_n \leq 360°$, for each wave number n.

Considering the phase angle ψ_n, it should be noted from equation (4) that the maxima in $T(\lambda)$ occur at $\lambda_{max} = (\psi_n + 2\pi M)/n$, $M = 0, \ldots, n-1$. In the statistics which follow, the primary phase ψ_n will be shown to be related to the correlation of harmonics between adjacent latitudes on a given day.

IV. SIGNIFICANCE OF THE POWER-SPECTRAL ESTIMATES AS FUNCTIONS OF SPACE WAVE NUMBER

A. PERCENTAGE EXPLAINED VARIANCE BY WAVE NUMBER ALOND KEY LATITUDES.

One of the results generated in this study, was the percentage of explained variance along each of the eight key latitudes for each of the map times. These are examined to determine which of the harmonics $N = 1, \ldots, 18$ provided significant contribution to the overall variance $\sigma^2(\phi, k)$, i.e., variance at a specific latitude at a specific time.

A two-way analysis of variance involving both spatial and temporal periodicity of the waves was not performed because of the small sample of lags between individual maps (namely $k = 14$). Instead, it was decided to compile a census only of those harmonics N which passed a significance test, an F-test for one-way analysis of variance along the latitude ϕ.

B. APPLICATION OF THE F-TEST AT HARMONIC WAVE N

The F-statistic defined by the influence of the Nth harmonic on the total variance σ^2 is

$$F_N = \frac{\% \text{ variance explained after wave } N, \text{ added}}{\% \text{ variance unexplained after wave } N} =$$

$$\frac{[(C_N^2/2\sigma^2)]/2}{\left[1 - \left(\sum_{n=1}^{N} C_n^2/2\sigma^2\right)\right]/(\eta - 2N-1)} \tag{8}$$

$$N = 1, \ldots, 18.$$

In equation (8), the division of the bracketed expression in the numerator by the factor 2 is necessitated by the use of two degrees of freedom employed when the Nth wave is added in equation (1), namely the specification of A_N, B_N at step N. On the other hand, in the bracketed expression of the denominator of equation (8), the integer divisor $(\eta - 2N-1)$ describes the fact that the mean percentage unexplained variance after N steps is associated with the remaining degrees of freedom at step N:

$$\text{D.F. (denominator)} = \eta - (2N+1)$$

Here $\eta = 72$ is the number of separate points used in computing the variance. Subtraction of 2N+1 expresses the fact that one degree of freedom has been used in evaluation of the mean, and the additional 2N have been used in determining the N harmonics to the Nth step in equation (1).

The F_N-statistics for each addition of one of the 18 waves around each latitude and for each time period was computed. This was completed using listings of the additional percentage of variance explained stepwise by waves N, N = 1, ..., 18. In order to estimate the significance at the 95% confidence level, the F_N-statistic was compared with a critical $F_N{}^c$ defined at 2 and 71-2N degrees of freedom. The critical $F_N{}^c$ at the 95% fiducial limits ranged monotomically between:

$$F_1{}^c = 3.15 \quad \text{to} \quad F_{18}{}^c = 3.28$$

as N ranges successively from N = 1 to N = 18. The tests showed that virtually none of the wave harmonics higher than n = 12 passed the significance test so that equation (1) was truncated at n = 12. The spectral density associated with waves 1 through 12 appear in Tables 1 through 4 and Tables 7 through 14. In

each of 12 tables, spectral densities are presented with respect to latitude (eight) and map time (15). The last two lines of these tables list the mean and standard deviation of the time-array of the power-spectral values for the sampling period. An asterisk indicates those particular cases for wave contributions which failed to qualify as significant at the 95% level. It is to be noted in general, that as N increases, fewer numbers in Tables 7 through 14 qualify as significant.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	8.31	8.76	5.63	1.13 *	11.19	18.41	58.03	12.34
2	14.53	2.14 *	6.33	14.64	15.61	5.84 *	36.13	13.32
3	3.54	17.46	9.05	25.16	19.98	6.86 *	36.57	18.72
4	9.14	4.79	11.49	30.89	18.25	4.19 *	34.68	18.58
5	4.81	24.03	0.89 *	8.06	6.36 *	1.00 *	51.90	26.27
6	8.15	13.79	1.42	17.21	8.05	4.33 *	85.69	16.28
7	6.96	11.91	1.66	37.81	4.25 *	5.35 *	60.60	8.63
8	13.61	8.85	1.68 *	23.38	15.01	20.73	30.26	20.49
9	2.34	15.45	1.56	25.09	7.30 *	29.92	50.82	3.20 *
10	8.14	20.20	2.47 *	15.16	7.28	7.20 *	36.26	23.39
11	5.05	14.23	1.33*	20.43	18.42	8.62	53.03	0.51 *
12	19.59	34.63	2.52	21.47	27.47	31.80	44.44	11.98
13	13.99	25.04	0.01 *	19.25	33.17	40.79	18.20	7.92
14	7.47	0.42*	0.34 *	9.36	24.91	73.90	32.10	16.21
15	12.16	7.53	5.12	24.65	6.01 *	27.37	29.91	4.73 *
MEAN	9.19	13.95	3.43	19.58	14.88	19.09	43.91	13.50
SD	4.58	8.98	3.27	8.92	8.50	16.90	16.04	7.25

Table 1. Contribution to the power spectrum for wave number 1 for individual map times k = 1, ..., 15, and by selected key latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	2.33	15.40	0.29 *	21.29	32.82	47.18	63.51	10.83
2	6.22	15.74	8.90	21.81	18.02	48.96	6.42 *	18.79
3	1.00 *	2.45 *	9.53	32.52	27.48	56.52	40.77	9.29
4	1.21 *	11.87	2.98	11.05	7.02 *	47.60	63.87	6.05
5	0.70 *	2.85 *	0.05 *	10.25	23.53	31.46	125.23	1.64
6	0.16 *	0.07 *	0.59 *	2.93 *	9.58	44.99	87.77	2.93
7	4.89	9.43	1.52	9.50	24.97	84.46	65.82	10.67
8	1.72	2.81	0.13 *	8.16	53.30	70.76	58.51	7.26
9	0.50 *	2.24 *	0.02 *	0.60 *	18.40	92.16	151.92	7.23
10	2.89	6.20	0.35 *	5.70 *	20.18	45.24	84.56	4.25
11	0.66	1.55 *	1.13 *	5.16 *	16.27	44.08	64.98	17.76
12	1.35 *	7.68	1.43 *	8.34	22.21	187.77	46.28	4.00 *
13	1.46	1.46 *	0.83 *	8.32	26.37	69.16	42.24	14.40
14	1.42	2.59	2.82	6.41	6.33	57.68	69.05	4.30
15	2.56 *	3.31	0.99 *	25.24	15.72	45.56	51.84	5.58
MEAN	1.94	5.71	2.10	11.82	21.48	64.91	68.18	8.33
SD	1.62	4.98	2.93	8.79	11.20	36.49	33.72	5.09

Table 2. Contribution to the power spectrum for wave number 2 for individual map times k = 1,...,15, and by selected key latitudes φ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	0.94*	10.06	5.33	0.20*	15.38	9.71	9.10	12.65
2	1.84	1.19*	6.51	6.83	4.77*	16.23	0.44*	11.84
3	1.51	8.37	4.63	3.39*	6.17	9.56	4.25	0.83*
4	0.75*	4.85	0.22*	11.53	6.72*	2.22*	11.81	1.52*
5	5.27	3.09	0.11*	8.78	3.09*	2.00*	8.09	7.60
6	5.69	8.06	0.35*	15.05	10.66	6.36	9.17	3.39
7	7.32	6.99	3.82	20.69	4.39	2.81*	10.87	2.68
8	1.22	4.93	2.30*	16.12	2.19*	11.91	8.65	6.74
9	5.84	0.06*	2.69	19.34	15.07	4.82*	18.80	5.65
10	8.50	3.28	4.27	25.79	4.17	14.57	13.06	3.40*
11	2.07	2.21	0.06*	14.74	1.39*	0.48*	16.10	0.03*
12	0.56*	15.52	3.38	11.61	2.37*	22.39	49.42	9.56
13	0.48*	0.13*	0.21*	3.04	19.66	15.65	22.11	1.65*
14	0.42*	0.37*	0.46*	13.65	6.45	20.25	33.27	1.11*
15	5.00	0.26*	10.58	29.12	13.84	13.16	13.22	5.34
MEAN	3.16	4.62	3.00	13.33	7.76	10.14	15.22	4.93
SD	2.69	4.32	2.91	7.97	5.53	6.69	11.84	3.89

Table 3. Contribution to the power spectrum for wave number 3 for individual map times k = 1,...,15, and by selected kay latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% lavel using the F test.

φ\k	50S	30S	15S	5S	5N	15N	30N	50N
1	0.10*	3.45	3.09	10.97	5.99	13.73	18.49	0.37*
2	2.71	8.64	2.79	14.30	10.39	40.94	12.82	5.16
3	0.53*	1.92*	0.93*	4.49*	10.48	6.99	9.70	13.65
4	3.18	1.65*	1.68*	13.28	19.66	12.72	11.79	3.37
5	1.19	4.14	7.78	0.51*	15.74	16.33	30.04	1.46
6	0.30*	1.32*	1.73	0.42*	11.10	10.54	10.99	4.38
7	7.06	0.98*	3.52	18.13	0.27*	19.46	3.43*	0.04*
8	3.99	2.71	5.49	8.25	2.76*	5.95	0.01*	1.78
9	1.56	1.80*	3.39	12.33	26.07	5.77	5.86	2.56*
10	2.43	1.62	14.15	19.46	9.26	7.63	9.28	6.75
11	1.37	2.28	1.72	16.52	3.07*	7.64	8.86	11.32
12	0.72*	0.18*	9.51	10.06	47.19	27.71	5.59	6.13
13	1.95	0.17*	5.57	7.26	10.52	2.54	2.26*	5.97
14	6.97	3.10	3.38	5.80	10.61	8.21	11.77	3.93
15	5.44	6.13	1.47	18.69	6.86	20.96	7.45	24.44
MEAN	2.63	2.61	4.41	10.70	12.67	13.74	9.89	6.09
SD	2.22	2.24	3.51	6.01	11.21	9.75	7.01	6.11

Table 4. Contribution to the power spectrum for wave number 4 for individual map times k = 1,...,15, and by selected key latitudes φ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

V. CORRELATION OF FEATURES ACROSS KEY LATITUDES

A. CORRELATION RELATIONSHIPS BY FOURIER ANALYSIS

It should be noted that in IV, it was found that in the mean at any given map time and along a key latitude, an average of 93% of the explained variance could be accounted for by the first 18 harmonics and 89% by the first 12 harmonics. The reduction to 12 harmonics was made on the basis of removal of the higher wave numbers which failed to yield significant F-levels.

It is desired now to determine the usefulness of the specification of $T(\lambda)$ in the form (4) on the basis of computations which involve the phase angles ψ_n at two adjacent key latitudes ϕ_1, ϕ_2 as these have been identified in II. Thus, the Fourier series

$$T_1(\lambda) = T_{o,1} + \sum_{n=1}^{12} C_{n1} \cos(n\lambda - \psi_{n1}) \qquad (10)$$

$$T_2(\lambda) = T_{o,2} + \sum_{n=1}^{12} D_{m2} \cos(m\lambda - \psi_{m2}) \qquad (11)$$

are defined at ϕ_1, ϕ_2, respectively. Correlation between values at identical longitudes along the adjacent latitudes are determined from the deviations $T_1'(\lambda)$, $T_2'(\lambda)$ from the respective zonal means:

$$r_{12} = \frac{1}{2\pi\sigma_1\sigma_2} \oint_0^{2\pi} T_1'(\lambda)\, T_2'(\lambda)\, d\lambda =$$

$$= \frac{1}{2\pi\sigma_1\sigma_2} \oint_0^{2\pi} \sum_{n=1}^{12} C_{n1} \cos(n\lambda - \mathcal{V}_{n1}) \sum_{n=1}^{12} D_{m2}$$

$$\cos(m\lambda - \mathcal{V}_{m2}) \, d\lambda \qquad (12)$$

The right side of (12) represents the integration of 144 combinations of products of form:

$$\frac{1}{2\pi\sigma_1\sigma_2} \oint_0^2 C_{n1} D_{m2} \cos(n\lambda - \mathcal{V}_{n1}) \cos(m\lambda - \mathcal{V}_{m2}) \, d\lambda$$

$$= \frac{C_n D_m}{2\pi\sigma_1\sigma_2} \oint_0^2 \frac{1}{2} \left\{ \cos[(n-m)\lambda - (\mathcal{V}_{n1} - \mathcal{V}_{m2})] \right.$$

$$\left. - \cos[(n+m)\lambda - (\mathcal{V}_{n1} - \mathcal{V}_{m2})] \right\} \, d\lambda \qquad (13)$$

Because of the closed integration, the second-term within the braces of the last expression must always integrate to zero for all combinations of n,m. The first term inside the braces also integrates to zero whenever $n \neq m$. Thus the original integral (12), which represents the simple correlation coefficient (r_{12}) is reducible to the sum of 12 terms as follows:

$$r(T_1', T_2') = \frac{1}{2\pi} \oint_0^{2\pi} \sum_{n=1}^{12} \frac{C_{n1} D_{n2}}{2\sigma_1\sigma_2} \cos(\mathcal{V}_{n1} - \mathcal{V}_{n2}) \, d\lambda$$

or

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$$\frac{1}{2N}\frac{\Phi}{\pi}\int_0^{\infty}\sum_{n=1}^{\infty}\binom{N}{n}\cdots\sum_{n=1}^{12} \cdots$$

$$\cdots \frac{N}{2N}\cdots$$ (2)

The right side of (2) represents the integration of the distribution of form:

$$\frac{1}{2N}\frac{\Phi}{\pi}\int_0^{\infty}\cdots$$

$$\cdots \int_0^{\infty}\cdots \frac{\Phi}{\pi}\sum \cdots$$

$$\cdots$$

Because of the ... the ... will be ...

... equation ... with respect to ...

... hence the integral from ...

integral (2) ...

... as follows:

$$\sum_{n=1}^{\infty}\int_0^{\infty}\frac{\Phi}{\pi}\cdots$$

$$r_{12} = \sum_{n=1}^{12} \frac{C_{n1} \, D_{n2}}{2\sigma_1 \sigma_2} \cos(\mathcal{Y}_{n1} - \mathcal{Y}_{n2}) \tag{14}$$

It is well known that if the amplitudes C_{n1}, D_{n1} are relatively small compared to the values required for significance, the corresponding phase angles cannot be resolved satisfactorily. Moreover the angle ($\mathcal{Y}_{n1} - \mathcal{Y}_{n2}$) can range from values within ± 90 degrees which gives a positive contribution to (14); and to negative values for the range $90 < /\mathcal{Y}_{n1} - \mathcal{Y}_{n2}/ < 270$ degrees, which represents essentially an out-of-phase relationship for waves n across latitudes ϕ_1, ϕ_2. The important point to be noted is that regardless of the significance of a phase-difference, the cosine of this angle carries the built-in weighting factor $C_n \, D_n/2\sigma_1 \sigma_2$ so that insignificant contributions to the sum (14) are self-eliminating. The results of the correlation coefficients (r_{12}) for pairs of key latitudes are shown in Table 5.

B. CORRELATION RESULTS USING CONVENTIONAL SAMPLING

A second method of computing r_{12} is to use the pairs of $T_1'(\lambda)$, $T_2'(\lambda)$, computed across successive key latitudes. This correlation coefficient is defined by the formula:

$$r_{12} = \sum_{i=1}^{\eta=72} \frac{T_{1,i}' \, T_{2,i}'}{\sigma_1 \sigma_2} \tag{15}$$

The results of these computations are shown in Table 6 and are seen to agree very well with those of Table 5.

In general, correlations between adjacent key latitudes in the Northern Hemisphere are larger than the correlations for the Southern Hemisphere. In particular,

ℓ/ϕ	5OS-3OS	3OS-15S	15S-5S	5S-5N	5N-15N	15N-3ON	3ON-5ON
1	-.341	0.033	0.228	0.353	0.188	0.475	0.387
2	-.586	-.068	0.285	0.316	0.533	0.479	0.525
3	0.004	-.105	0.178	0.589	0.422	0.447	0.512
4	0.178	0.201	0.385	0.154	0.203	0.177	0.334
5	-.212	0.110	0.068	0.236	0.001	0.209	0.366
6	-.318	0.016	-.096	0.205	-.066	0.465	0.324
7	-.090	-.136	0.097	0.243	-.090	0.598	0.259
8	-.438	0.010	0.320	0.292	0.136	0.594	0.359
9	-.256	0.073	0.331	0.488	0.221	0.603	0.062
10	-.386	0.048	0.161	0.399	0.441	0.718	0.456
11	-.560	-.042	0.390	0.589	0.261	0.582	0.128
12	-.402	0.095	0.534	0.559	0.458	0.622	0.587
13	-.550	-.058	0.316	0.383	0.186	0.577	-.031
14	-.148	0.855	0.389	0.442	0.219	0.492	0.118
15	-.113	-.104	0.162	0.341	0.180	0.571	0.221

Table 5. Correlation coefficients computed using equation (14) for adjacent latitudes for 15 time periods.

φ / ℓ	50S-30S	30S-15S	15S-5S	5S-5N	5N-15N	15N-30N	30N-50N
1	-.360	0.024	0.228	0.369	0.186	0.465	0.370
2	-.584	-.069	0.293	0.238	0.556	0.479	0.555
3	-.051	-.114	0.162	0.599	0.380	0.448	0.511
4	0.188	0.209	0.384	0.128	0.168	0.144	0.329
5	-.160	0.111	0.058	0.269	0.042	0.180	0.352
6	-.329	0.005	0.013	0.182	-.074	0.447	0.308
7	-.064	-.132	0.117	0.246	-.103	0.598	0.219
8	-.408	0.007	0.338	0.303	0.122	0.591	0.323
9	-.264	0.057	0.335	0.469	0.202	0.575	0.057
10	-.394	0.027	0.145	0.428	0.472	0.697	0.451
11	-.529	-.061	0.428	0.588	0.261	0.568	0.119
12	-.393	0.066	0.541	0.598	0.448	0.622	0.533
13	-.588	-.079	0.297	0.281	0.187	0.593	-.040
14	-.154	0.990	0.360	0.456	0.216	0.468	0.124
15	-.117	-.112	0.172	0.346	0.173	0.558	0.223

Table 6. Correlation coefficients computed using equation (15) for adjacent latitudes for 15 time periods.

the correlation for 15-30N is generally high for the entire period, indicating that the events or weather patterns at 30N are very similar to those at 15N. This high correlation is not present for 15-30S. It is interesting to note that highly consistant negative correlation can only take place when the phase angles are out of phase, that is, they have the range $90 < /\gamma_{n1} - \gamma_{n2}/ < 270$ degrees. This indicates an independence of events or weather patterns between 30-50S. Since this negative correlation exists between 30-50S for almost the entire 75 day period, we should be able to observe physically different weather patterns along the same longitude at the two latitudes for any given period or for the mean map for the entire period. Patterns that would give the out-of-phase relationship noted for 30-50S are not apparent in Figures 1 through 6 because in such depictions the smaller wave number features mask them. It can be seen, however, that the long-wave patterns are out of phase for these latitudes and it is this long wave negative contribution to the correlation coefficient that is dominant. When only the contributions from the first four waves were considered in equation (14), the correlation coefficient values for 30-50S were essentially as listed in Tables 5 or 6. This confirms the statistical results concerning 30-50S.

There are high correlations between all latitudes in the Northern Hemisphere for periods 12 and 10 and for 15-30N for period 11. Figure 5 is a mean for the above three periods and should provide a sample of weather patterns that are in phase. With some difficulty one can determine the long wave pattern along 15-30N. The long wave pattern is essentially the same for both latitudes, in particular wave 2 can be discerned with a maximum over Africa and one over the Pacific. In summary, a high correlation between latitudes indicates that a simi-

lar weather pattern exists over both latitudes and that the weather pattern is

essentially in phase in the north-south direction.

VI. DISTRIBUTION OF VARIANCE AMONG THE MAJOR WAVES

A. THE ZONAL MEANS AND VARIANCE AT KEY LATITUDES

High values of variance indicate large variability in the cloud cover along the latitude ϕ. The NIMBUS II temperatures sensed vary considerably from one period to another as well as around a latitude. It should be recalled that single events such as a single cumulo-nimbus are not observed since each of the periods was a five-day composite of cloud conditions, therefore variability is a description of larger-scale events.

Figures 7 and 8 depict the total variance for the key latitudes considered in both hemispheres. The larger variances in the Northern Hemisphere during the period should be noted. Because of the distribution of continents and oceans in the Northern Hemisphere and their respective zonal temperature differences, the variance for the Northern Hemisphere was expected to be larger than for the Southern Hemisphere with its predominance of ocean area. Figure 1, which is the mean map for the 75 day period essentially shows the climatological state with alternate cold and warm cells in the Northern Hemisphere and an absence of these structures in the Southern Hemisphere. These cellular patterns would produce higher variances in the Northern Hemisphere.

Figure 9 displays the mean temperatures T_o versus time. The relatively small amplitude time-traces of T_o reinforces the conclusion that the Southern Hemisphere is more stable in its radiometric climatology than the comparable latitudes of the Northern Hemisphere. Smoothed curve tracings in Figure 9 also show a
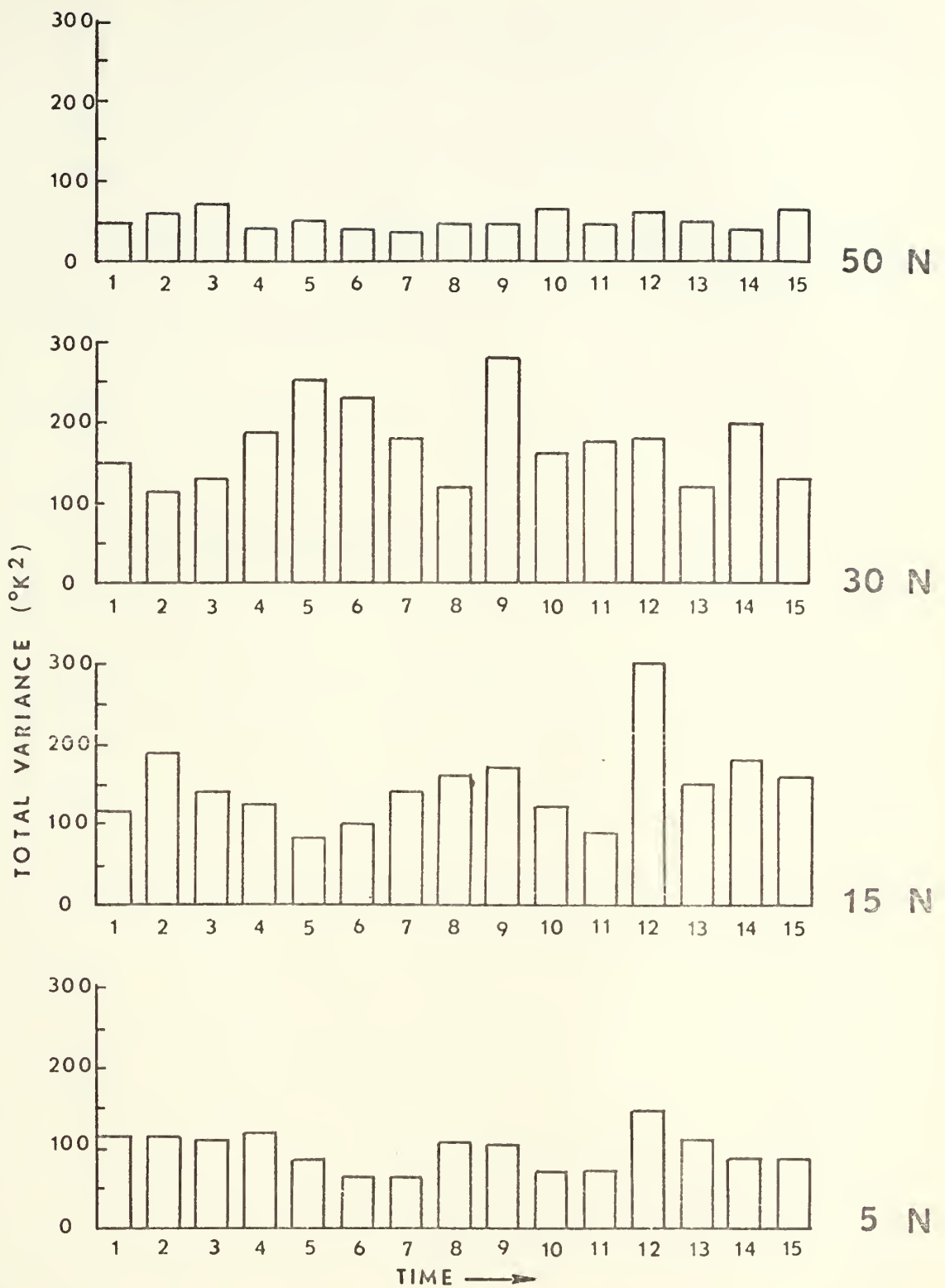
Figure 7. Total variance versus time for selected latitudes in the Northern Hemisphere.

35
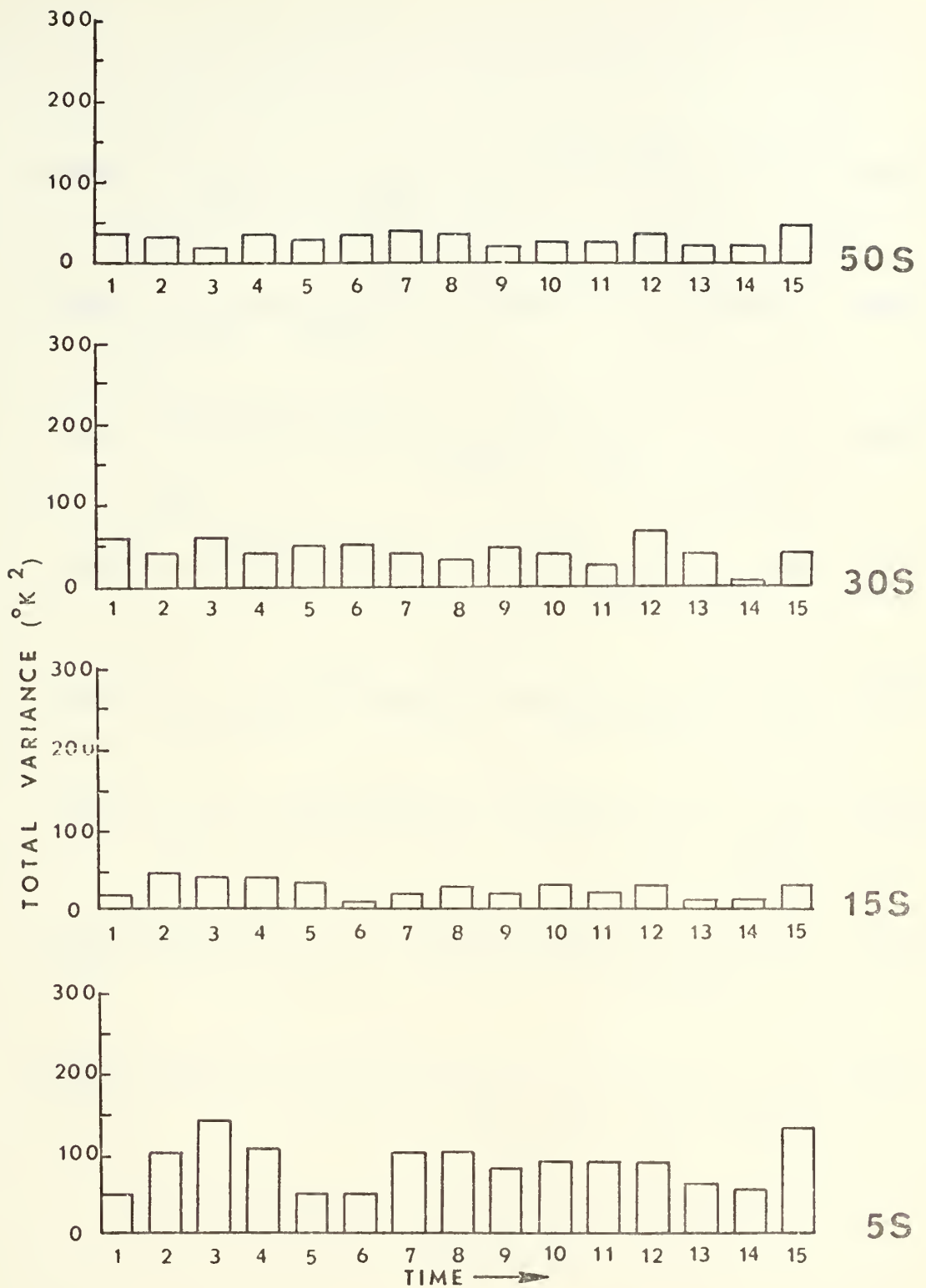
Figure 8. Total variance versus time for selected latitudes in the Southern Hemisphere.
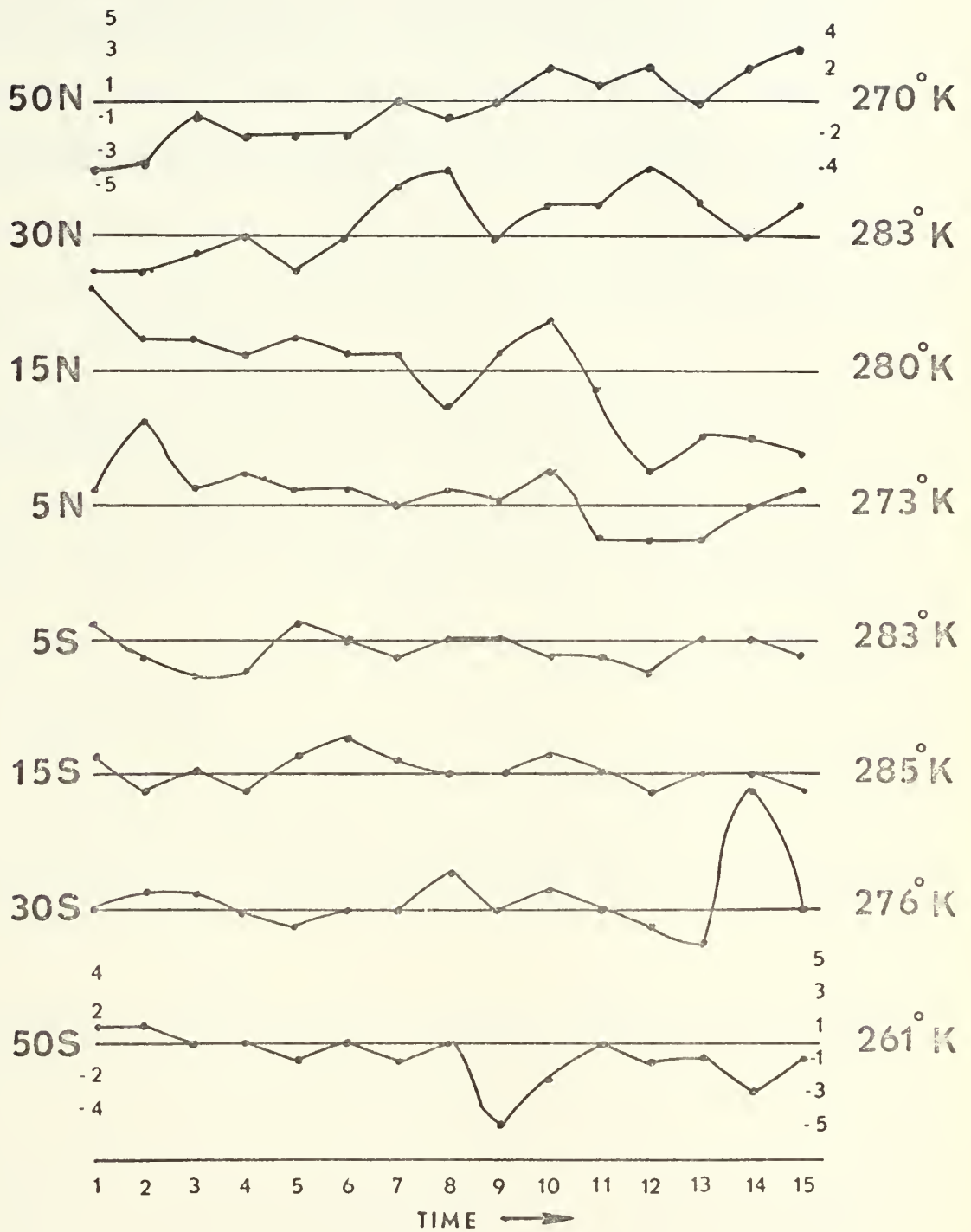
Figure 9. Zonally averaged temperatures (T_o) for selected latitudes versus time. The scale in degrees indicated at 50N is applicable to the remaining latitudes.

general warming tendency for latitudes 30 and 50N during the overall period of the Northern Hemisphere summer, while there is a general cooling at latitudes 15N and 5N. In addition latitudes 15N and 5N have a lower mean temperature for the 75 day period than does latitudes 15S and 5S, indicating the proximity of large-scale cloud build-ups associated with the ITCZ. This situation is reversed for the more poleward latitudes, 30S and 50S, which have lower temperatures during the period than 30N and 50N.

B. DISTRIBUTION OF PERCENTAGE EXPLAINED VARIANCES AMONG THE MAJOR WAVES

Figures 10 and 11 represent percentage contribution to variance by the first eight waves. Another way to visualize Figures 10 and 11 is as variance contributions by waves one through eight, relative to the total variance normalized to unity for each latitude.

The first observation is that the first four waves in the Northern Hemisphere contribute more to the variance than in the Southern Hemisphere. Thus, the contribution of percentage variance for waves 5 through 12 is more significant for the Southern Hemisphere.

The second observation is that wave 2 is a dominant contributer in all northern latitudes but is minimally represented in southern latitudes. Wave 2 has been described as being a reflection of the land-sea distribution around a latitude. The large contribution by wave 2 in the Northern Hemisphere cases and its relative absence in the Southern Hemisphere supports this description.

Both at 15N and 15S one observes from Figures 10 and 11 a minimum contribution by wave 1. In the case of 15N, the small contribution to variance by wave

38
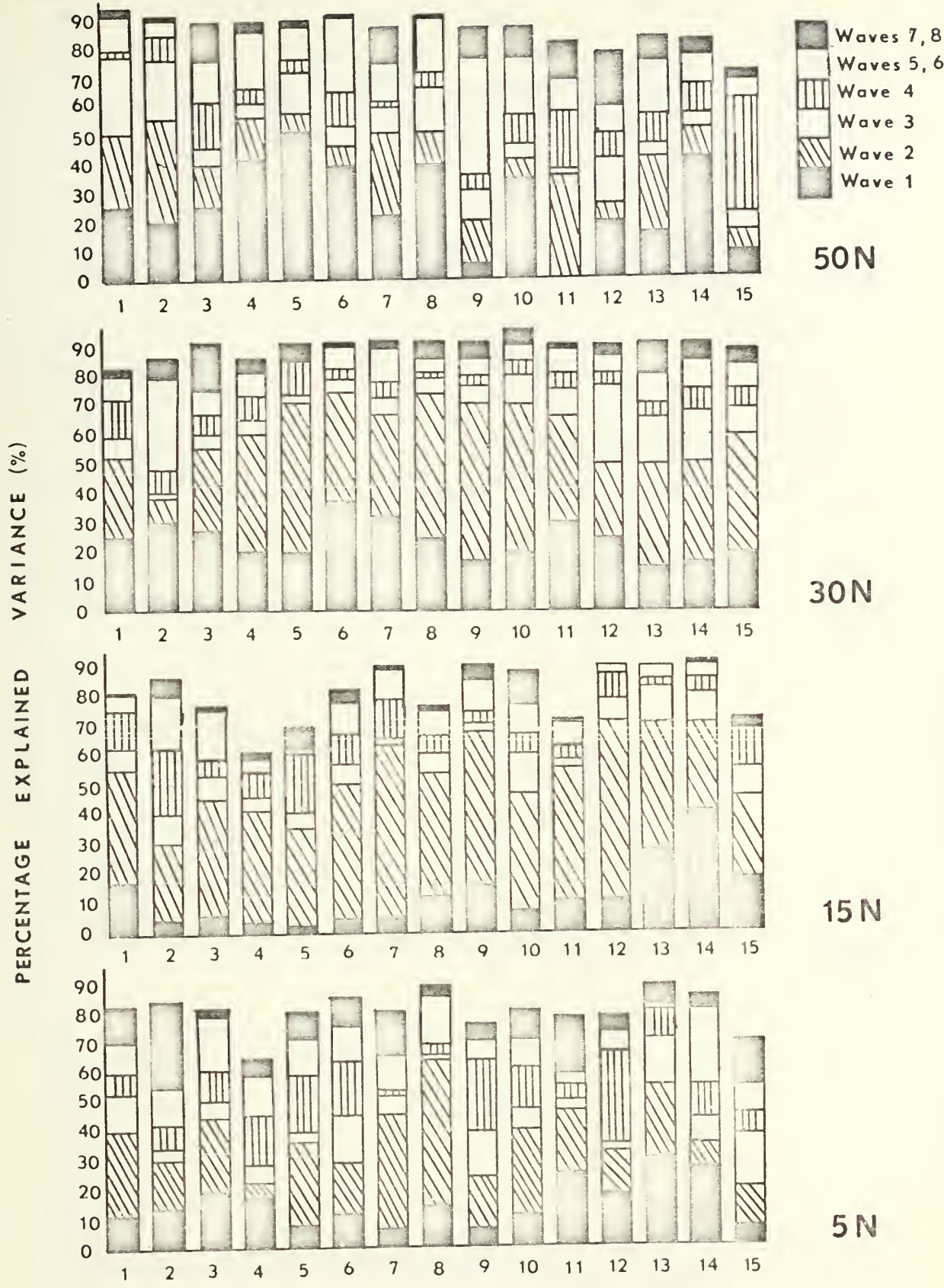
Figure 10. Percentage explained variance versus time for selected latitudes in the Northern Hemisphere contributed by waves 1 through 8.

39
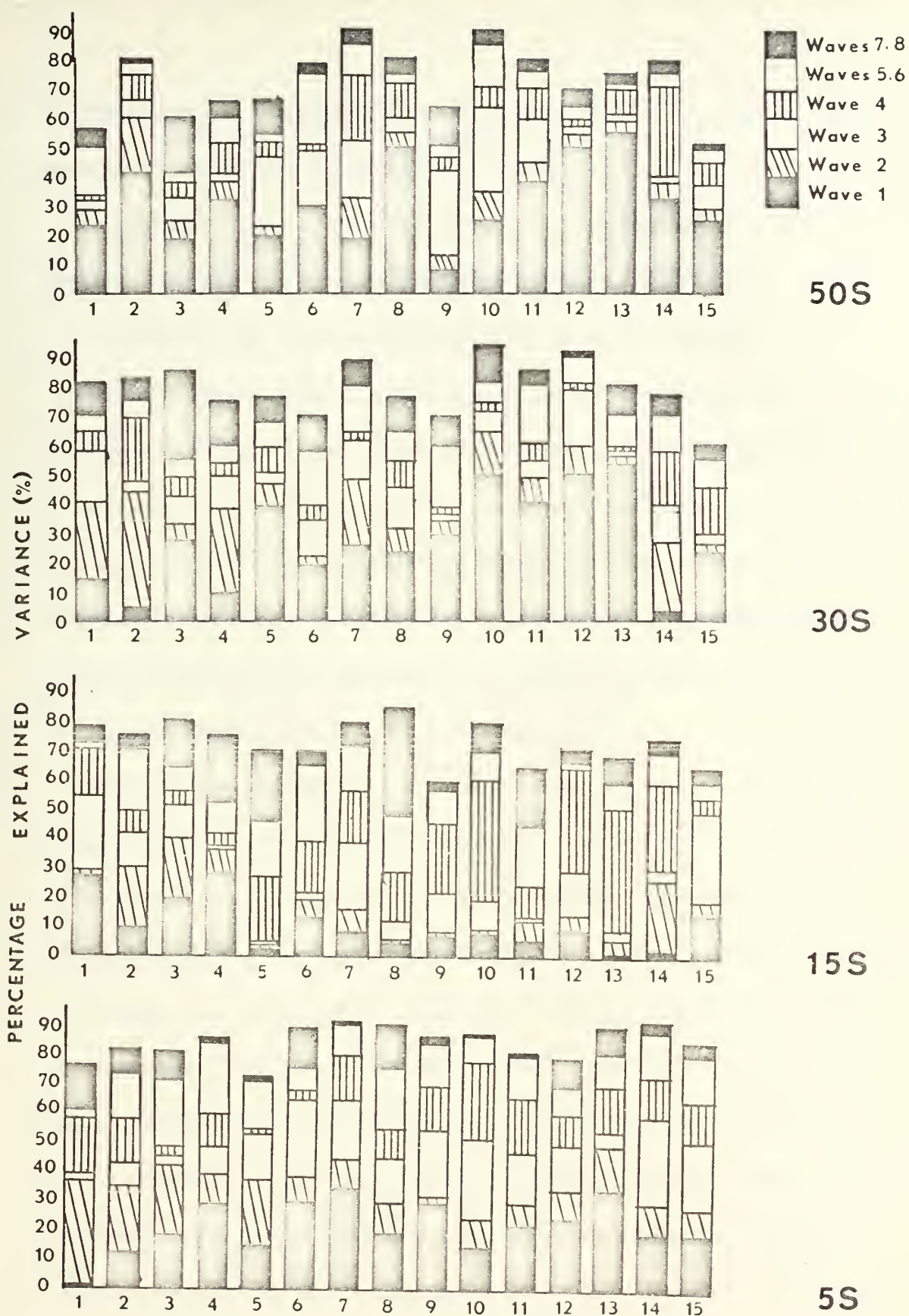
Figure 11. Percentage explained variance versus time for selected latitudes in the Southern Hemisphere contributed by waves 1 through 8.

40

1 is compensated by large contributions by wave 2, but for 15S, waves 3 and 4 make up in part for the small contribution by wave 1.

Overall, the largest contribution to variance is made by wave 1, but for the Northern Hemisphere alone wave 2 contributes most to the variance.

C. CONTRIBUTIONS TO VARIANCE BY HIGHER WAVE NUMBERS

We now focus our attention primarily upon the wave number groups $n = 5$-6 and 7-8 to look for sources of additional normalized variance (called ANV) beyond those just studied in VI-B. Our tests for statistical significance have led us to examine the significance of these middle-scale waves in pairs since the noise superimposed upon the data sample tends to move the line-spectral effects from one wave-number to an adjacent one. Figures 10 and 11 also display the contributions by the pairs of wave numbers 5-6 and 7-8.

If one uses the Southern Hemisphere as a preliminary guide, it is clear that substantial added variance is often accounted for by considering the contributions by the general wave group 5-8 inclusive. The effects of the additional normalized variance (ANV) are most marked at 15S, where it comprised as much as 50% in one case. The values of ANV at 15S seem to deviate about a mean of 25%, with a minimum of 10% and the maximum of 50%. At both 5S and 30S, the values of ANV are also substantial in waves 5-8, but somewhat smaller than at 15S, in magnitude. The average increment was about 20% with a range averaging from 15% to 25%. There was a slightly more definitive trend for additional variance to be manifested in wave group 5-6 than 7-8. The ANV's for all three latitudes tended to be nearly in phase date-wise.

The added variance by the wave-group 5-8 at 50S is smaller, averaging approximately 10% with a correspondingly smaller deviation about the mean at 50S. No marked preference is shown for the number-group 5-6 relative to 7-8. The consideration of even more harmonics beyond n = 8 may be indicated from the fact that now (with n = 1,..,8 included) the normalized variance fails to exceed 70% in six of the fifteen periods at 50S.

In the Northern Hemisphere, the pattern of additional normalized variance (ANV) is quite different to that just described for the Southern Hemisphere. Now the maximum ANV is located at 50N, with a secondary maximum at 5N, followed by a tertiary maximum at 30N and the minimum ANV at 15N. Here we are speaking of average values of ANV of 25% at both 50N and 5N, and of 15% ± 5% in the 15-30N zone.

In the Northern Hemisphere, peak values of ANV tend to occur within phase across the latitudes if a tolerance of one map is allowed.

In the Northern Hemisphere, with waves 1 to 8 specifying the variance at generally over 75%, there is little further noise-free variance to account for. In the Southern Hemisphere, there were indeed some map periods when more variance could be accounted for by combinations of waves in the group 9-12, but these did not seem to afford any systematic time-sequence across the key latitudes. Hence, the analysis of variance attributed to waves 9-12 suggests that the detection of additional normalized variance is not likely to refine the climatology further.

VII. CONCLUSION

The large climatological features can be described by analysis of window-channel temperatures as sensed by satellites at some synoptic-scale space-smoothing interval. Fourier analysis provides a tool which is useful in describing the larger scale weather events. Fourier analysis results indicate clearly many differences in the Northern-Southern Hemispheric weather patterns.

The large climatological feature can be described by analysis of station-channel temperatures as sensed by satellite at some synoptic scale in the corresponding interval. For the analysis provides a tool which is useful in describing the larger scale weather events. Profile analysis results indicate clearly several effects in the Northern-Southern Hemisphere weather surface.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	1.75*	2.61	0.11*	1.10*	2.00*	4.63	1.61*	3.79
2	0.55*	0.73*	9.80	15.49	3.71*	24.69	15.82	1.58
3	0.22*	0.20*	2.27	16.95	14.90	10.92	1.19*	7.38
4	0.10*	0.05*	4.69	24.53	8.68	1.70*	0.89*	7.66
5	0.25*	0.90*	3.04	6.65	6.93	0.10*	0.15*	3.29
6	4.03	2.63*	0.42*	3.00	5.67	2.98	1.83*	6.21
7	0.69*	5.48	1.78	8.19	6.78	2.70	10.52	0.19*
8	0.54*	1.01*	0.29*	13.31	15.82	3.32*	0.57*	3.13
9	0.92*	2.68*	0.80*	9.16	3.84	13.36	11.53	18.62
10	3.74	0.00*	2.89	8.75	6.06	4.11	0.89*	7.42
11	0.0*	4.99	0.95*	10.25	2.14*	0.61*	13.14	0.99*
12	1.23*	4.90	0.03*	4.08	8.36	1.72*	5.32	4.71
13	0.53*	3.24	0.42*	5.64	1.34*	7.89	2.50*	4.38
14	0.32*	0.97	0.83	6.12	10.44	1.80*	2.95*	4.01
15	1.06*	3.42	0.68*	15.22	5.69	0.75*	7.10	4.29
MEAN	1.06	2.25	1.93	9.90	6.83	5.42	5.07	5.18
SD	1.19	1.81	2.46	6.01	4.18	6.35	5.06	4.21

Table 7. Contribution to the power spectrum for wave number 5 for individual map times $k = 1, \ldots, 15$, and by selected key latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	2.69	0.88*	0.16*	0.11*	8.99	3.47	14.46	0.88
2	1.12	1.23	0.55*	2.80	10.39	0.91	20.49	0.84
3	0.24*	3.45	3.00	11.05	7.17	10.44	6.97	3.51
4	1.92	2.78	0.52*	0.12*	7.05	2.94	9.82	0.74
5	0.19*	4.11	3.15	1.46	3.49	2.42	0.18*	2.72
6	2.23	7.07	2.41	1.27	1.43*	7.07	13.59	3.87
7	3.04	1.78	0.97	2.18	0.85*	12.75	9.61	5.20
8	0.37*	2.69	4.45	8.97	2.41	10.35	3.33	7.64
9	0.42*	9.78	0.08*	2.50	2.96*	4.47	1.89*	2.29
10	0.25*	2.25	0.94	0.13*	0.24*	6.24	3.93	5.61
11	0.26*	1.58	3.05	1.08*	0.18*	14.39	4.39	4.12
12	1.18*	0.54	0.27*	1.69*	3.49*	4.95	7.14	2.74
13	0.21*	2.18	0.88	2.87	1.62*	0.39	10.34	5.79
14	0.56*	0.58	0.47	0.25*	9.19	4.56	15.30	0.64*
15	0.82*	0.72*	0.89*	6.38	2.29*	2.33	6.05	0.51*
MEAN	1.03	2.77	1.45	2.67	4.12	5.85	8.50	3.14
SD	0.94	2.49	1.33	3.22	3.36	4.17	5.45	2.15

Table 8. Contribution to the power spectrum for wave number 6 for individual map times k = 1,...,15, and by selected key latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	0.64*	5.80	0.47*	5.59	4.15	0.41*	0.98*	0.46*
2	0.20*	1.23	1.08*	9.65	5.58	3.74	1.88	0.33*
3	0.53*	14.03	4.33	15.59	2.13	0.11*	11.74	0.28*
4	1.45	5.56	6.50	1.07*	3.05*	1.52*	5.03	0.36*
5	0.22*	1.23*	1.03*	2.13	2.93	4.21	3.97	0.14*
6	0.18*	3.92	0.34*	0.39*	0.75*	0.38*	0.90*	0.51*
7	2.24	3.51	0.89	0.56*	1.66*	2.67	7.62	0.03*
8	0.92	2.94	7.94	9.15	0.53*	1.73*	6.75	0.62
9	2.96	4.69	1.78	0.01*	1.11*	2.20	14.54	2.58
10	0.23*	2.26	0.98	0.84	3.83	9.50	6.25	5.83
11	0.81	0.58	1.71	0.70*	4.72	1.84*	2.21	1.96
12	2.03	0.42*	0.25*	3.17	2.31*	0.65*	0.77*	7.99
13	0.41*	3.84	0.12*	1.66	1.61*	0.06*	9.20	2.22
14	0.23*	0.41*	0.47	1.32	2.70	1.22*	4.25	1.76
15	5.56	1.64	1.10*	0.94*	6.21	5.82	5.25	1.70*
MEAN	1.24	3.47	1.94	3.52	2.89	2.44	5.42	1.78
SD	1.42	3.32	2.31	4.38	1.67	2.45	3.94	2.20

Table 9. Contributions to the power spectrum for wave number 7 for individual map times $k = 1, \ldots, 15$, and by selected key latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

k\ϕ	50S	30S	15S	5S	5N	15N	30N	50N
1	3.75	0.12*	0.56	4.48	9.50	1.61*	1.08*	0.12*
2	0.10*	1.85	1.33	0.25*	25.47	8.18	6.03	0.09*
3	3.49	2.78	3.26	0.54*	0.17*	0.85*	5.09	9.59
4	0.71*	0.51*	1.53	1.22	3.66*	1.06*	3.63	1.02
5	2.39	3.76	4.71	4.27	2.94	2.26*	6.67	1.22
6	0.91	2.76	0.14*	6.71	5.39	5.32	1.64*	0.54
7	0.17*	0.10*	0.50	0.45*	7.93	0.56*	0.07*	4.69
8	0.14*	2.13	3.12	7.11	3.02	4.35	1.13*	0.15*
9	0.16*	0.72	0.22*	2.01	5.12	7.25	1.38*	2.51
10	0.93	1.87	2.81	0.15*	1.94	1.22*	1.13*	1.97
11	0.00*	0.59	1.60	1.17	9.13	0.98*	0.33*	4.87
12	0.38*	0.0 *	1.08	5.36	2.61*	0.65*	5.81	4.46
13	0.32*	1.15	0.74	2.30	4.21	0.48*	4.19	2.69
14	0.70	0.20*	0.17*	0.50*	2.92	2.97	8.02	0.77*
15	0.73*	0.90*	0.10*	3.52	8.56	2.05*	0.16*	0.25*
MEAN	0.99	1.30	1.46	2.67	6.17	2.65	3.09	2.33
SD	1.17	1.13	1.36	2.33	5.83	2.41	2.59	2.54

Table 10. Contributions to the power spectrum for wave number 8 for individual map times k = 1,...,15, and by selected key latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	4.86	0.46*	0.66	5.07	2.02*	3.68	5.02	0.66
2	0.50*	2.05	5.48	3.71	1.55*	7.36	0.54*	0.38*
3	0.43*	0.25*	1.82	3.04	1.74*	3.39	1.89*	0.85
4	0.30*	2.77	2.27	1.67	2.38*	4.00*	5.60	1.97
5	1.18	1.58	0.74*	2.47	0.01*	2.71	3.36	0.03*
6	0.31*	5.81	0.29*	0.75	0.86*	0.93*	0.23*	0.01*
7	0.08*	0.04*	1.04	0.39*	2.13	1.51	0.38*	1.03
8	0.92*	1.45	0.40*	0.10*	1.05*	10.39	1.39	3.31
9	1.90	0.45*	1.34	4.02	1.87*	0.09*	11.67	0.57*
10	0.20*	0.00*	1.40	0.36*	0.79*	2.29	3.50	1.91
11	0.05*	0.26*	1.82	0.19*	0.84*	2.17	0.81*	0.94*
12	1.79	0.18*	0.18*	3.01	4.11	1.78*	2.89	2.15
13	0.85	2.53	0.59	0.73	0.50*	1.12*	1.14	0.07*
14	0.36*	0.01*	0.03*	0.38*	2.94	0.67*	2.28	0.47*
15	0.30*	4.61	0.95*	1.83*	0.66*	0.48*	0.91*	0.21*
MEAN	0.94	1.50	1.27	1.85	1.56	2.84	2.77	0.97
SD	1.19	1.73	1.29	1.56	1.03	2.68	2.97	0.92

Table 11. Contributions to the power spectrum for wave number 9 for individual map times k = 1,...,15, and by selected key latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	2.40	1.26	0.13*	1.99	2.80	0.15*	3.23	0.45*
2	0.61*	0.11*	1.52	1.78	4.51	0.49*	0.02*	0.38*
3	0.57*	1.85	0.09*	1.73*	1.40*	3.14*	2.43	0.43*
4	0.48*	0.80*	0.92	1.89	3.47*	6.84	4.40	0.54
5	0.11*	0.22*	1.26	0.39*	1.57*	0.13*	6.90	0.10*
6	0.61*	1.59	0.59	0.13*	0.69*	1.34*	5.35	0.06*
7	0.02*	0.11*	0.24	0.91	2.22	0.21*	4.49	0.76
8	0.37*	1.96	0.28*	0.05*	1.03*	6.40	3.01	0.12*
9	0.86	3.78	0.40*	0.46*	2.54	4.63	0.70*	0.67*
10	0.22*	0.48	0.86	1.68	2.56	1.91	1.08	0.25*
11	0.41	1.53	0.17*	1.41*	3.19	2.62	7.05	2.04
12	1.65	0.67	1.75	2.71	2.50*	4.46	0.81*	1.23
13	0.43*	1.94	1.14	0.30*	0.61*	1.04*	0.38*	0.38*
14	0.41*	0.71	0.63	0.20*	4.19	1.41*	1.52*	0.13*
15	0.62*	0.39*	2.11	0.49*	1.18*	4.44*	0.41*	0.34*
MEAN	0.65	1.16	0.81	1.08	2.30	2.61	2.78	0.53
SD	0.59	0.95	0.61	0.82	1.17	2.19	2.30	0.50

Table 12. Contributions to the power spectrum for wave number 10 for individual map times k = 1,...,15, and by selected key latitudes φ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

k\φ	50S	30S	15S	5S	5N	15N	30N	50N
1	1.39	0.27*	0.19*	0.33*	1.34*	2.15	1.17*	0.68
2	0.09*	0.55	0.06*	2.83	1.45	4.56	0.03*	2.03
3	0.29*	0.17*	0.19*	1.94*	1.32*	1.21*	0.92*	1.05
4	0.28*	1.26	0.64	0.01*	9.22	10.25	1.02*	0.32*
5	0.80	0.16*	0.60*	0.06*	0.40*	4.82	0.48*	0.70
6	1.53	0.20*	0.44	0.80	1.14	0.59*	2.43	1.04
7	0.43	0.39*	0.03*	0.66*	1.31	0.10*	1.39	0.20*
8	0.67	0.76	1.39	1.15	0.70*	8.15	0.23*	0.15*
9	1.16	0.65*	1.99	0.28*	5.61	1.56	0.59*	2.05
10	0.41	0.50	0.66	0.09*	0.77*	2.99	0.17*	1.89
11	0.04*	0.47	1.06	3.13	2.95	2.65	1.48	0.58*
12	0.71	0.37*	1.02	3.09	0.89*	0.80*	0.41*	0.52*
13	0.66	0.98	0.33	0.27*	0.57*	1.06*	0.0* *	1.67
14	0.13*	0.23	0.26	0.05*	0.03*	1.65	3.45	0.63*
15	2.89	0.37*	2.75	3.69	4.21	4.77	2.51	0.24*
MEAN	0.77	0.49	0.78	1.23	2.13	3.15	1.09	0.92
SD	0.72	0.30	0.74	1.29	2.39	2.81	0.99	0.65

Table 13. Contributions to the power spectrum for wave number 11 for individual map times k = 1,...,15, and by selected kay latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

$k \backslash \phi$	50S	30S	15S	5S	5N	15N	30N	50N
1	0.59*	0.63*	0.52	0.05*	0.13*	0.57*	0.13*	0.37*
2	0.11*	0.04*	0.95	2.58	1.13*	1.66	0.35*	0.06*
3	0.05*	1.08	0.40*	2.40	1.80	0.38*	2.00	0.89
4	0.02*	0.07*	0.28*	0.14*	1.08*	4.82	3.56	0.09*
5	1.04	1.15*	0.83*	0.25*	2.38	2.81	8.01	0.65
6	0.40	0.31*	0.02*	0.04*	0.10*	3.73	1.62	0.20*
7	0.41	0.11*	0.07*	0.93	0.38*	0.73*	1.73	1.99
8	0.67	1.34	0.08*	0.94	0.18*	1.70	0.10*	0.88
9	0.51*	0.09*	0.24*	0.42*	1.63*	1.16	2.09	0.80
10	0.16*	0.33	0.13*	0.30*	0.11*	0.31*	0.05*	0.17*
11	0.34	0.37	0.17*	0.90*	2.16	1.14	1.62	1.89
12	0.03*	1.15	0.86	0.10*	3.57	2.34*	1.83	0.45*
13	0.65	0.55	0.02*	0.15*	0.55*	0.47*	0.97*	0.98
14	0.06*	0.02*	0.02*	0.78	0.07*	0.54*	2.48	0.32
15	2.40	0.15*	0.44*	2.71	4.20	0.98*	0.04*	0.72*
MEAN	0.50	0.49	0.34	0.85	1.30	1.56	1.77	0.64
SD	0.58	0.45	0.31	0.92	1.27	1.29	1.95	0.49

Table 14. Contributions to the power spectrum for wave number 12 for individual map times k = 1, ..., 15, and by selected key latitudes ϕ. Included for each latitude is the time-mean and standard deviation (SD). Units: degrees Kelvin squared. Values followed by an * did not qualify on the 95% level using the F test.

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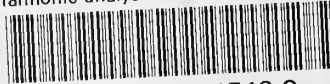| 1 ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Naval Postgraduate School Monterey, California 93940	Unclassified
	2b. GROUP

3 REPORT TITLE

Harmonic Analysis of Satellite Sensed Temperatures Along Latitudes
of Both Hemispheres for the Period 15 May to 28 July 1966

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)
Master's Thesis; September 1971

5. AUTHOR(S) (First name, middle initial, last name)

Lieutenant Commander John J. Krall, USN

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1971	55	3

8a. CONTRACT OR GRANT NO	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

The object of the study is to examine the climatology of NIMBUS II satellite-sensed window-channel equivalent blackbody temperatures for the period 15 May to 28 July 1966. Fourier analysis was applied to these temperatures at selected latitudes in the Northern and Southern Hemispheres.

The total variance, as well as the percentage contribution to variance by individual waves 1 through 8, along the selected latitudes is examined. In addition, correlation coefficients between adjacent key latitudes are computed and interpreted.

DD FORM 1473 (PAGE 1)
1 NOV 65

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
EQUIVALENT BLACKBODY TEMPERATURE						
NIMBUS II SATELLITE						
WINDOW-CHANNEL TEMPERATURE						
FOURIER ANALYSIS						
EXPLAINED VARIANCE						
SATELLITE CLIMATOLOGY						
KEY-LATITUDE ANALYSIS						